HETEROGENEOUS SHALLOW-SHELF CARBONATE BUILDUPS IN THE PARADOX BASIN, UTAH AND COLORADO: TARGETS FOR INCREASED OIL PRODUCTION AND RESERVES USING HORIZONTAL DRILLING TECHNIQUES

SEMI-ANNUAL TECHNICAL PROGRESS REPORT October 6, 2004 - April 5, 2005

by

Thomas C. Chidsey, Jr., Principal Investigator/Program Manager, and
Craig D. Morgan
Utah Geological Survey,
and
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UTAH GEOLOGICAL SURVEY

April 2005

Contract No. DE-FC26-00BC15128

Virginia Weyland, Contract Manager
U.S. Department of Energy
National Petroleum Technology Office
1 West 3rd Street
Tulsa, OK 74103-3532

DISCLAIMER

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Submitting Organization: Utah Geological Survey
1594 West North Temple, Suite 3110
P.O. Box 146100
Salt Lake City, Utah 84114-6100
(801) 537-3300

ABSTRACT

The Paradox Basin of Utah, Colorado, Arizona, and New Mexico contains nearly 100 small oil fields producing from carbonate buildups within the Pennsylvanian (Desmoinesian) Paradox Formation. These fields typically have one to 10 wells with primary production ranging from 700,000 to 2,000,000 barrels (111,300-318,000 m^3) of oil per field and a 15 to 20 percent recovery rate. At least 200 million barrels (31.8 million m^3) of oil will not be recovered from these small fields because of inefficient recovery practices and undrained heterogeneous reservoirs.

Several fields in southeastern Utah and southwestern Colorado are being evaluated as candidates for horizontal drilling and enhanced oil recovery from existing vertical wells based upon geological characterization and reservoir modeling case studies. Geological characterization on a local scale is focused on reservoir heterogeneity, quality, and lateral continuity, as well as possible reservoir compartmentalization, within these fields. This study utilizes representative cores, geophysical logs, and thin sections to characterize and grade each field's potential for drilling horizontal laterals from existing development wells. The results of these studies can be applied to similar fields elsewhere in the Paradox Basin and the Rocky Mountain region, the Michigan and Illinois Basins, and the Midcontinent region.

This report covers research activities for the second half of the fifth project year (October 6, 2004 through April 5, 2005). The work included cathodoluminescence analyses of selected reservoir rocks from Cherokee and Bug fields, San Juan County, Utah. Cathodoluminescence is the emission of light resulting from the bombardment of materials using a cathode ray. This technique provides important information about the complex modification of rock fabrics and porosity within the lower Desert Creek and upper Ismay zones of the Blanding sub-basin. Examination of dolomites in these zones under cathodoluminescence makes it possible to more clearly identify grain types and shapes, early cements, and brecciated phylloid-algal mound fabrics. In addition, identification of pelleted fabrics in muds, as well as various types of skeletal grains, is improved by cathodoluminescence examination in rocks where these grains have been poorly preserved, partially leached or completely dolomitized.

Cathodoluminescence imaging clearly and rapidly images pore spaces that cannot be easily seen in standard viewing under transmitted, plane-polarized lighting. In addition, the cross sectional size, shape, and boundaries of pores are easy to determine. This information is often very useful when considering the origin and timing of dolomitization as well as evaluating the quality of the pore system within the dolomite.

Examination of saddle dolomites, when present within the clean carbonate intervals of the upper Ismay or lower Desert Creek interval, can provide more information about these late, elevated temperate (often hydrothermal) mineral phases. For instance, saddle dolomites often showed nice growth banding. They also exhibited the difference between replacement and cement types of saddle dolomites under cathodoluminescence.

Technology transfer activities for the reporting period consisted of a publication and distributing a press release requesting industry proposals for drilling a horizontal well(s) in the Ismay or Desert Creek zones as part of the Phase II Demonstration. The project home page was updated for the Utah Geological Survey Web site.

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EXECUTIVE SUMMARY

The project's primary objective is to enhance domestic petroleum production by demonstration and transfer of horizontal drilling technology in the Paradox Basin of Utah and Colorado. If this project can demonstrate technical and economic feasibility, then the technique can be applied to approximately 100 additional small fields in the Paradox Basin alone, and result in increased recovery of 25 to 50 million barrels (4-8 million m^3) of oil. This project is designed to characterize several shallow-shelf carbonate reservoirs in the Pennsylvanian (Desmoinesian) Paradox Formation, choose the best candidate field(s) for a pilot demonstration project to drill horizontally from existing vertical wells, monitor well performance, and report associated validation activities.

The Utah Geological Survey heads a multidisciplinary team to determine the geological and reservoir characteristics of typical, small, shallow-shelf, carbonate reservoirs in the Paradox Basin. The Paradox Basin technical team consists of the Utah Geological Survey (prime contractor), Colorado Geological Survey (subcontractor), Eby Petrography & Consulting Inc. (subcontractor), and Seeley Oil Company (subcontractor and industry partner). This research is partially funded by the Class II Oil Revisit Program of the U.S. Department of Energy, National Petroleum Technology Office (NPTO) in Tulsa, Oklahoma. This report covers research activities for the second half of the fifth project year (October 6, 2004 through April 5, 2005). The work included cathodoluminescence analyses of selected reservoir rocks from Cherokee and Bug fields, San Juan County, Utah. From these and other project evaluations, untested or under-produced reservoir compartments and trends can be identified as targets for horizontal drilling. The results of this study can be applied to similar reservoirs in many U.S. basins.

Cathodoluminescence is the emission of light resulting from the bombardment of materials using a cathode ray. This petrographic technique can be an invaluable tool in petrographic studies of carbonate rocks. It provides important information about the complex modification of rock fabrics and porosity within the lower Desert Creek and upper Ismay zones of the Blanding sub-basin. Examination of upper Ismay limestones and lower Desert Creek dolomites under cathodoluminescence makes it possible to more clearly identify grain types and shapes, early cements (such as botryoidal, fibrous marine, bladed calcite cements), and brecciated phylloid-algal mound fabrics. In addition, identification of pelleted fabrics in muds, as well as various types of skeletal grains, is improved by cathodoluminescence examination in rocks where these grains have been poorly preserved, partially leached or completely dolomitized. In many ways, cathodoluminescence imaging of samples nicely complements the types of information derived from epifluorescence of carbonate thin sections.

Cathodoluminescence imaging clearly and rapidly images pore spaces that cannot be easily seen in standard viewing under transmitted, plane-polarized lighting. In addition, the cross sectional size, shape, and boundaries of pores are easy to determine. This information is often very useful when considering the origin and timing of dolomitization as well as evaluating the quality of the pore system within the dolomite.

Imaging of microfractures as well as dissolution along microstylolites, is greatly facilitated under cathodoluminescence. Many open microfractures cannot be easily seen in a normal 3-μm–thick petrographic thin section, especially within dense, lower Desert Creek dolomites. Routine cathodoluminescence examination of the same thin section often reveals the presence of individual microfractures or microfracture swarms.

Examination of saddle dolomites, when present within the clean carbonate intervals of the upper Ismay or lower Desert Creek interval, can provide more information about these late, elevated temperate (often hydrothermal) mineral phases. For instance, saddle dolomites from the Cherokee Federal No. 22-14 well showed nice growth banding. They also exhibited the difference between replacement and cement types of saddle dolomites under cathodoluminescence.

Technology transfer activities for the reporting period consisted of distributing a press release requesting industry proposals for drilling a horizontal well(s) in the Ismay or Desert Creek zones as part of the Phase II Demonstration. The project home page was updated on the Utah Geological Survey Web site. Project team members also published the semi-annual report detailing project progress and results.

INTRODUCTION

Project Overview

Over 400 million barrels (64 million m^3) of oil have been produced from the shallow-shelf carbonate reservoirs in the Pennsylvanian (Desmoinesian) Paradox Formation in the Paradox Basin, Utah and Colorado (figure 1). With the exception of the giant Greater Aneth field, the other 100-plus oil fields in the basin typically contain 2 to 10 million barrels (0.3-1.6 million m^3) of original oil in place. Most of these fields are characterized by high initial production rates followed by a very short productive life (primary), and hence premature abandonment. Only 15 to 25 percent of the original oil in place is recoverable during primary production from conventional vertical wells.

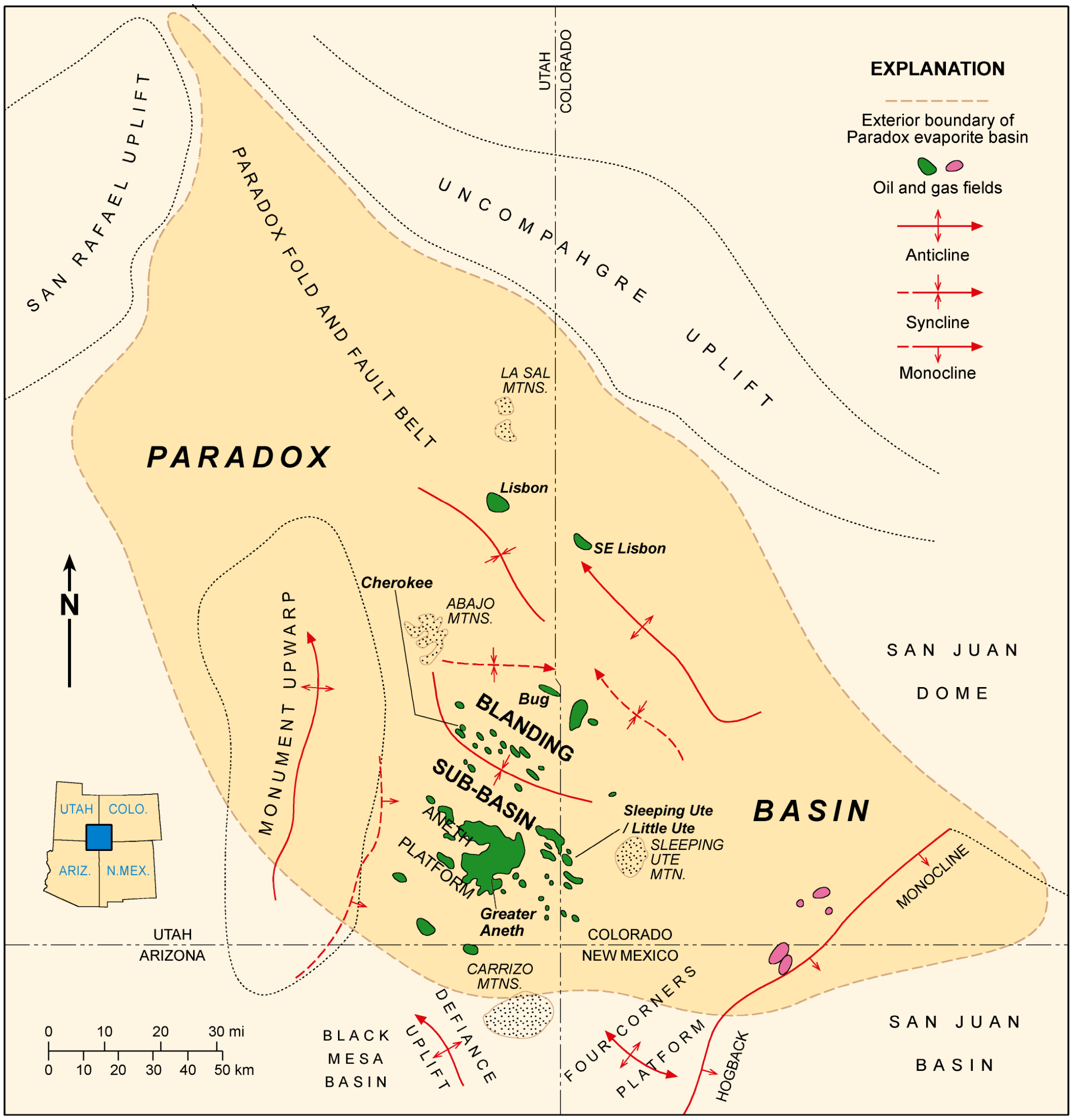


Figure 1. Location map of the Paradox Basin, Utah, Colorado, Arizona, and New Mexico, showing producing oil and gas fields, the Paradox fold and fault belt, and Blanding sub-basin as well as surrounding Laramide basins and uplifts (modified from Harr, 1996).

An extensive and successful horizontal drilling program has been conducted in the giant Greater Aneth field. However, to date, only two horizontal wells have been drilled in small Ismay and Desert Creek fields. The results from these wells were disappointing due to the previously poor understanding of the carbonate facies and diagenetic fabrics that create reservoir heterogeneity. These small fields, and similar fields in the basin, are at high risk of premature abandonment. At least 200 million barrels (31.8 million m^3) of oil will be left behind in these small fields because current development practices leave compartments of the heterogeneous reservoirs undrained. Through proper geological evaluation of the reservoirs, production may be increased by 20 to 50 percent through the drilling of low-cost, single, or multilateral horizontal legs from existing vertical development wells. In addition, horizontal drilling from existing wells minimizes surface disturbances and costs for field development, particularly in the environmentally sensitive areas of southeastern Utah and southwestern Colorado.

The Utah Geological Survey (UGS), Colorado Geological Survey (CGS), Eby Petrography & Consulting, Inc., and Seeley Oil Company have entered into a cooperative agreement with the U.S. Department of Energy (DOE) as part of its Class II Oil Revisit Program. A three-phase, multidisciplinary approach is planned to increase production and reserves from the shallow-shelf carbonate reservoirs in the Ismay and Desert Creek zones of the Paradox Basin.

<u>Phase 1</u> is a geological and reservoir characterization of selected, diversified, small fields, including Cherokee and Bug fields in San Juan County, Utah (figure 1), to identify those field(s) having the greatest potential as targets for increased well productivity and ultimate recovery in a pilot demonstration project. This phase includes: (a) determination of regional geological setting; (b) analysis of the reservoir heterogeneity, quality, lateral continuity, and compartmentalization within the fields; (c) construction of lithologic, microfacies, porosity, permeability, and net pay maps of the fields; (d) determination of field reserves and recovery; and (e) integration of geological data in the design of single or multiple horizontal laterals from existing vertical wells.

<u>Phase 2</u> is a field demonstration project of the horizontal drilling techniques identified as having the greatest potential for increased field productivity and ultimate recovery. The demonstration project will involve drilling one or more horizontal laterals from the existing, vertical, field well(s) to maximize production from the zones of greatest potential.

<u>Phase 3</u> includes: (a) reservoir management and production monitoring, (b) economic evaluation of the results, and (c) determination of the ability to transfer project technologies to other similar fields in the Paradox Basin and throughout the U.S.

Phases 1, 2, and 3 will have continuous, but separate, technical transfer activities including: (a) an industry outreach program; (b) a core workshop/seminar in Salt Lake City; (c) publications and technical presentations; (d) a project home page on the Utah Geological Survey and Colorado Geological Survey Web sites; (e) digital databases, maps, and reports; (f) a summary of regulatory, economic, and financial needs; and (g) annual meetings with a Technical Advisory Board and Stake Holders Board.

This report covers research activities for the second half of the fifth project year (October 6, 2004 through April 5, 2005). The work included cathodoluminescence analyses of selected reservoir rocks from Cherokee and Bug fields, San Juan County, Utah.

Project Benefits and Potential Application

The overall benefit of this multi-year project would be enhanced domestic petroleum production by demonstrating and transferring an advanced-oil-recovery technology throughout the small oil fields of the Paradox Basin. Specifically, the benefits expected from the project are: (1) increasing recovery and reserve base by identifying untapped compartments created by reservoir heterogeneity; (2) preventing premature abandonment of numerous small fields; (3) increasing deliverability by horizontally drilling along the reservoir's optimal fluid-flow paths; (4) identifying reservoir trends for field extension drilling and stimulating exploration in Paradox Basin fairways; (5) reducing development costs by more closely delineating minimum field size and other parameters necessary for horizontal drilling; (6) allowing for minimal surface disturbance by drilling from existing, vertical, field well pads; (7) allowing limited energy investment dollars to be used more productively; and (8) increasing royalty income to the federal, state, and local governments, the Ute Mountain Ute Indian Tribe, and fee owners. These benefits may also apply to other areas, including algal-mound and carbonate buildup reservoirs on the eastern and northwestern shelves of the Permian Basin in Texas, Silurian pinnacle and patch reefs of the Michigan and Illinois Basins, and shoaling carbonate island trends of the Williston Basin.

The results of this project are transferred to industry and other researchers through Technical Advisory and Stake Holders Boards, an industry outreach program, digital project databases, and project Web pages. Project results are also disseminated via technical workshops and seminars, field trips, technical presentations at national and regional professional meetings, and papers in various technical or trade journals.

GEOLOGIC SETTING

The Paradox Basin is located mainly in southeastern Utah and southwestern Colorado with small portions in northeastern Arizona and the northwestern corner of New Mexico (figure 1). The Paradox Basin is an elongate, northwest-southeast-trending, evaporitic basin that predominately developed during the Pennsylvanian (Desmoinesian), about 330 to 310 million years ago (Ma). During the Pennsylvanian, a pattern of basins and fault-bounded uplifts developed from Utah to Oklahoma as a result of the collision of South America, Africa, and southeastern North America (Kluth and Coney, 1981; Kluth, 1986), or from a smaller scale collision of a microcontinent with south-central North America (Harry and Mickus, 1998). One result of this tectonic event was the uplift of the Ancestral Rockies in the western United States. The Uncompahgre Highlands in eastern Utah and western Colorado initially formed as the westernmost range of the Ancestral Rockies during this ancient mountain-building period. The Uncompahgre Highlands (uplift) is bounded along the southwestern flank by a large basement-involved, high-angle, reverse fault identified from geophysical seismic surveys and exploration drilling. As the highlands rose, an accompanying depression, or foreland basin, formed to the southwest — the Paradox Basin. Rapid subsidence, particularly during the Pennsylvanian and then continuing into the Permian, accommodated large volumes of evaporitic and marine sediments that intertongue with non-marine arkosic material shed from the highland area to the northeast (Hintze, 1993). The Paradox Basin is surrounded by other uplifts and basins that formed during the Late Cretaceous-early Tertiary Laramide orogeny (figure 1).

The Paradox Basin can generally be divided into two areas: the Paradox fold and fault belt in the north, and the Blanding sub-basin in the south-southwest (figure 1). Most oil production comes from the Blanding sub-basin. The source of the oil is several black, organic-rich shales within the Paradox Formation (Hite and others, 1984; Nuccio and Condon, 1996). The relatively undeformed Blanding sub-basin developed on a shallow-marine shelf which locally contained algal-mound and other carbonate buildups in a subtropical climate.

The two main producing zones of the Paradox Formation are informally named the Ismay and the Desert Creek (figure 2). The Ismay zone is dominantly limestone, comprising equant buildups of phylloid-algal material with locally variable, small-scale subfacies (figure 3A) and capped by anhydrite. The Ismay produces oil from fields in the southern Blanding sub-basin (figure 4). The Desert Creek zone is dominantly dolomite, comprising regional, nearshore, shoreline trends with highly aligned, linear facies tracts (figure 3B). The Desert Creek produces oil in fields in the central Blanding sub-basin (figure 4). Both the Ismay and Desert Creek buildups generally trend northwest-southeast. Various facies changes and extensive diagenesis have created complex reservoir heterogeneity within these two diverse zones.

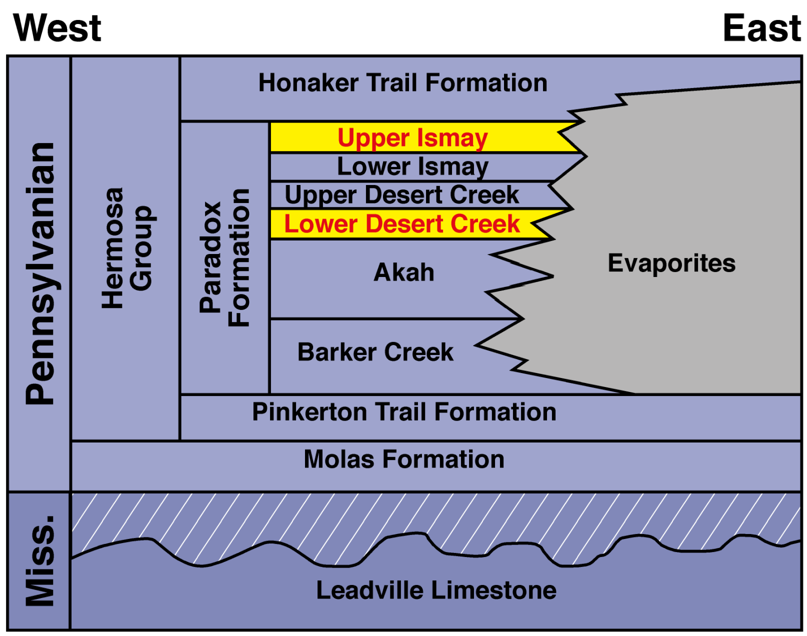


Figure 2. Pennsylvanian stratigraphy of the southern Paradox Basin including informal zones of the Paradox Formation; the Ismay and Desert Creek zones productive in the case-study fields described in this report are highlighted.

CASE-STUDY FIELDS

Two Utah fields were selected for local-scale evaluation and geological characterization: Cherokee in the Ismay trend and Bug in the Desert Creek trend (figure 4). The diagenetic evaluation summarized in this report, included cathodoluminescence (CL) examination, photomicroscopy, description, and interpretation of thin section samples from these fields.

This geological characterization focused on reservoir diagenesis, heterogeneity, quality, and lateral continuity, as well as possible compartmentalization within the fields. From these evaluations, untested or under-produced compartments can be identified as targets for horizontal drilling. The models resulting from the geological and reservoir characterization of these fields can be applied to similar fields in the basin (and other basins as well) where data might be limited.

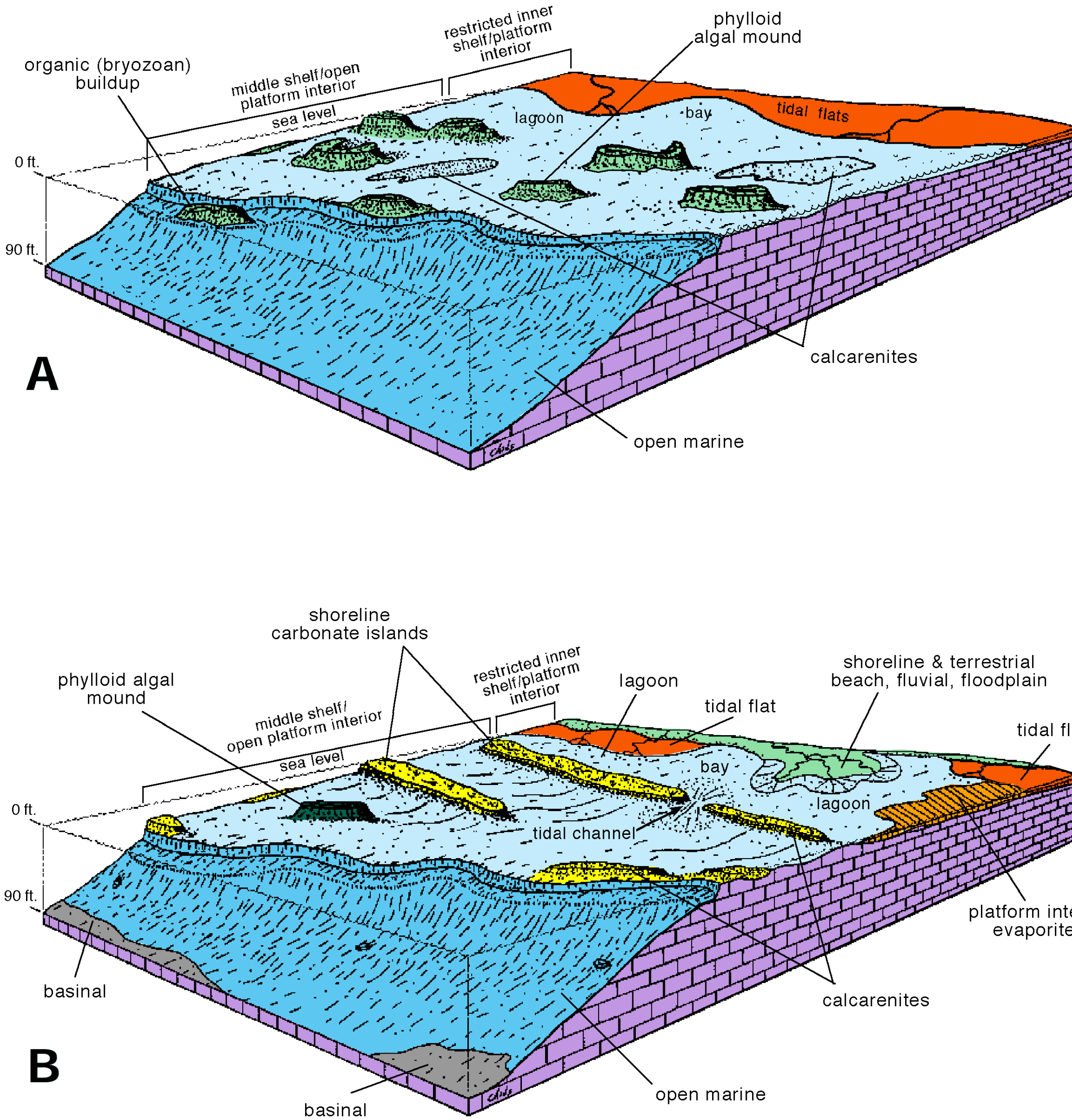


Figure 3. Block diagrams displaying major depositional facies, as determined from core, for the Ismay (A) and Desert Creek (B) zones, Pennsylvanian Paradox Formation, Utah and Colorado.

Cherokee Field

Cherokee field (figure 4) is a phylloid-algal buildup capped by anhydrite that produces from porous algal limestone and dolomite in the upper Ismay zone. The net reservoir thickness is 27 feet (8.2 m), which extends over a 320-acre (130 ha) area. Porosity averages 12 percent with 8 millidarcies (mD) of permeability in vuggy and intercrystalline pore systems. Water saturation is 38.1 percent (Crawley-Stewart and Riley, 1993).

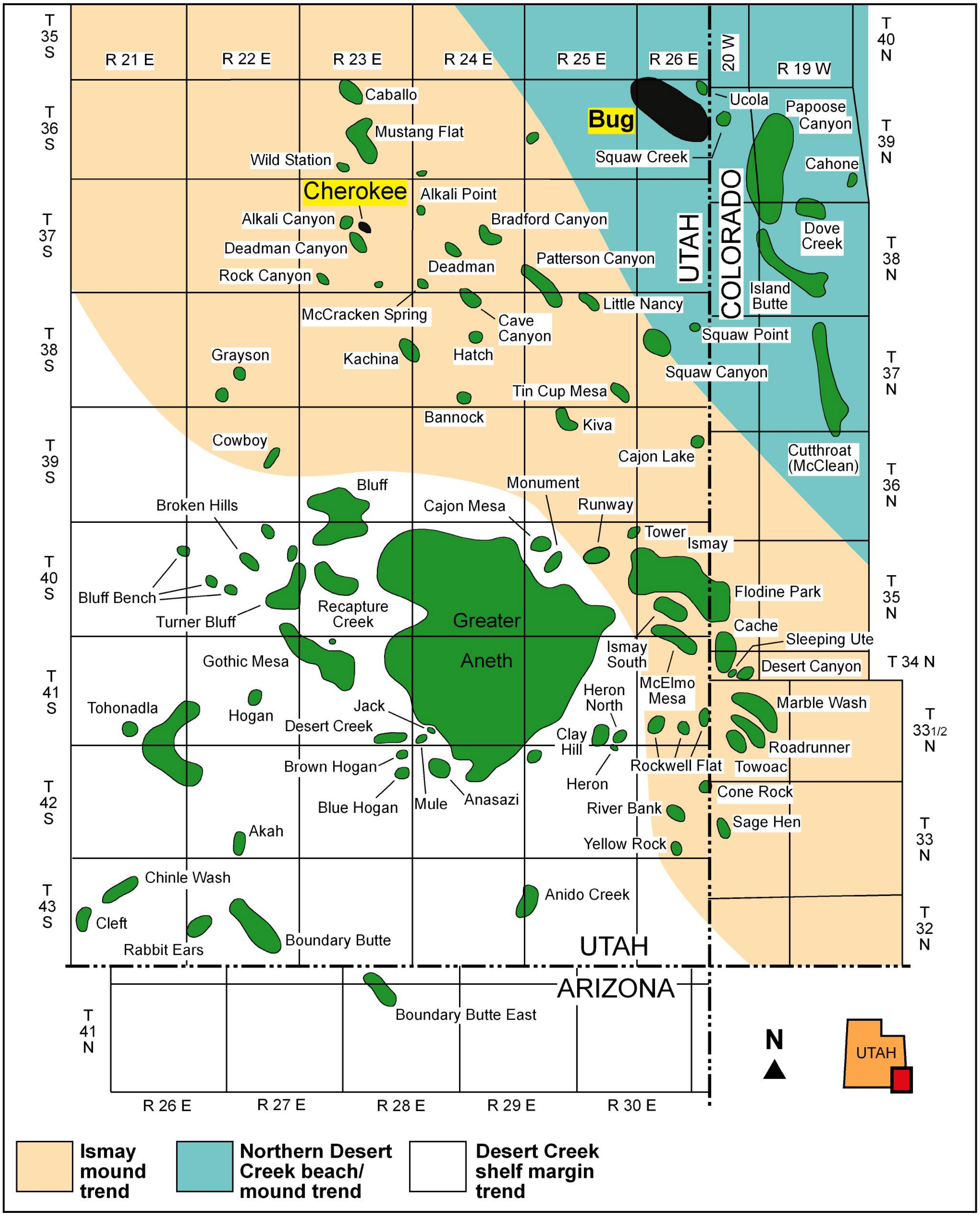


Figure 4. Project study area and fields (case-study fields in black) within the Ismay and Desert Creek producing trends in the Blanding sub-basin, Utah and Colorado.

Cherokee field was discovered in 1987 with the completion of the Meridian Oil Company Cherokee Federal 11-14, NE1/4NW1/4 section 14, T. 37 S., R. 23 E., Salt Lake Base Line and Meridian (SLBL&M); initial flowing potential (IFP) was 53 barrels of oil per day (BOPD) (8.4 m^3), 990 thousand cubic feet of gas per day (MCFGPD) (28 MCMPD), and 26 barrels of water (4.1 m^3). There are currently four producing (or shut-in) wells and two dry holes in the field. The well spacing is 80 acres (32 ha). The present field reservoir pressure is estimated at 150 pounds per square inch (psi) (1034 kPa). Cumulative production as of January 1, 2005, was 182,901 barrels of oil (29,081 m^3), 3.68 billion cubic feet of gas (BCFG) (0.1 BCMG), and 3358 barrels of water (534 m^3) (Utah Division of Oil, Gas and Mining, 2004). The original estimated primary recovery is 172,000 barrels of oil (27,348 m^3) and 3.28 BCFG (0.09 BCMG) (Crawley-Stewart and Riley, 1993). The fact that both these estimates have been surpassed suggests significant additional reserves could remain.

Bug Field

Bug field (figure 4) is an elongate, northwest-trending carbonate buildup in the lower Desert Creek zone. The producing units vary from porous dolomitized bafflestone to packstone and wackestone. The trapping mechanism is an updip porosity pinchout. The net reservoir thickness is 15 feet (4.6 m) over a 2600-acre (1052 ha) area. Porosity averages 11 percent in moldic, vuggy, and intercrystalline networks. Permeability averages 25 to 30 mD, but ranges from less than 1 to 500 mD. Water saturation is 32 percent (Martin, 1983; Oline, 1996).

Bug field was discovered in 1980 with the completion of the Wexpro Bug No. 1, NE1/SE1/4 section 12, T. 36 S., R. 25 E., SLBL&M, for an IFP of 608 BOPD (96.7 m^3), 1128 MCFGPD (32 MCMPD), and 180 barrels of water (28.6 m^3). There are currently eight producing (or shut-in) wells, five abandoned producers, and two dry holes in the field. The well spacing is 160 acres (65 ha). The present reservoir field pressure is 3550 psi (24,477 kPa). Cumulative production as of January 1, 2005, was 1,622,863 barrels of oil (258,035 m^3), 4.5 BCFG (0.13 BCMG), and 3,181,467 barrels of water (505,853 m^3) (Utah Division of Oil, Gas and Mining, 2004). Estimated primary recovery is 1,600,000 bbls (254,400 m^3) of oil and 4 BCFG (0.1 BCMG) (Oline, 1996). Again, since the original reserve estimates have been surpassed and the field is still producing, significant additional reserves likely remain.

CATHODOLUMINESCENCE

Introduction

Cathodoluminescence is the emission of light resulting from the bombardment of materials using a cathode ray (Allan and Wiggins, 1993). This petrographic technique can be an invaluable tool in petrographic studies of carbonate rocks. This technique can provide important information about the complex modification of rock fabrics and porosity within the lower Desert Creek and upper Ismay zones of the Blanding sub-basin. Diagenesis played a major role in the development of reservoir heterogeneity in Bug and Cherokee fields as well as throughout the all of the Paradox Formation fields. Diagenetic processes started during deposition and continued throughout burial history (figure 5). A complete discussion on the diagenetic history based upon visual core examination and thin section petrography was

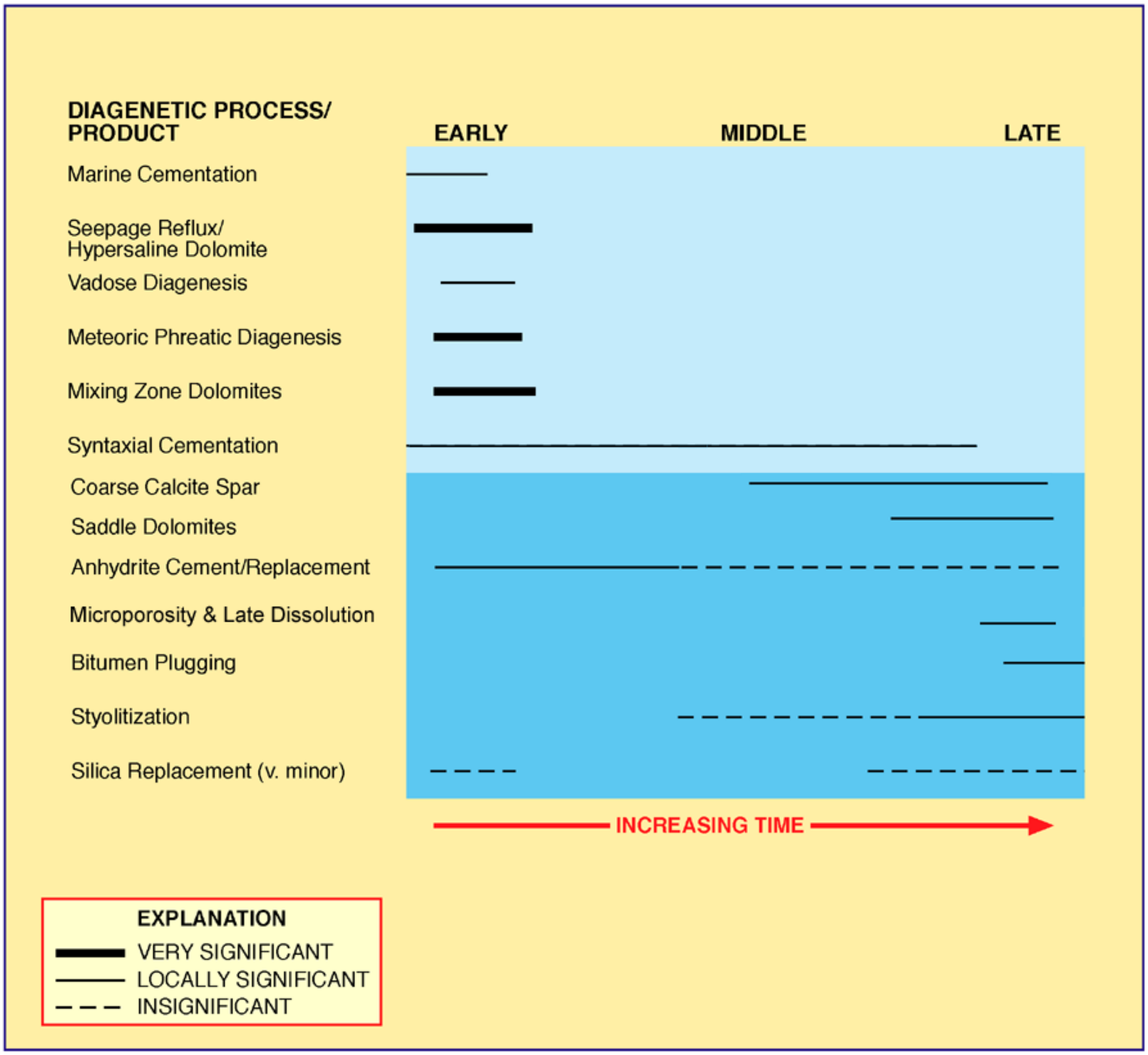


Figure 5. Ideal diagenetic sequence through time based on thin section analysis, Ismay and Desert Creek zones, Cherokee and Bug fields.

documented previously in **Deliverable 1.2.1A – Thin Section Descriptions: Cherokee and Bug Fields, San Juan County, Utah.**

Cathodoluminescence has been used in recent years to provide insights into the chemical differences between preserved remnants of depositional components resulting from various diagenetic events in carbonate rocks as recognized from core examination and thin section petrography. In particular, CL provides visual information on the spatial distribution of certain trace elements, especially manganese (Mn^{2+}) and iron (Fe^{2+}) in calcites and dolomites (Machel and Burton, 1991; Scholle and Ulmer-Scholle, 2003). The visible CL responses are red to orange in color, and their intensity is usually described as non-luminescent, dully luminescent, and brightly luminescent. As a general rule, incorporation of Mn^{2+} into the calcite lattice stimulates luminescence and the incorporation of Fe^{2+} quenches or reduces luminescence (Fairchild, 1983; Allan and Wiggins, 1993; Scholle and Ulmer-Scholle, 2003). Qualitative interpretation of CL usually assigns nonluminescent responses to oxidizing settings in which the reduced forms of both Mn and Fe are unavailable for incorporation into the lattices of carbonate mineral precipitates. Oxidized forms of Mn and Fe are not incorporated into calcite or dolomite crystals. Therefore, there is nothing in these crystals to excite luminescence. Bright luminescence is related to carbonate precipitates with high Mn/Fe trace element ratios, typically as a result of reducing environments during early (near-surface) to intermediate stages of burial diagenesis. Dull luminescence seems to happen where the Mn/Fe trace element ratios are present in carbonate precipitates. Thus, dull luminescence is usually thought to be the result of intermediate to late stages of burial diagenesis. It appears that elements other than Mn and Fe do not have any appreciable effect in enhancing or reducing luminescence (Budd and others, 2000).

Particularly useful references on the uses and limitations of CL interpretations in ancient carbonate studies include Sipple and Glover (1965), Frank and others (1982, 1996), Marshall (1988), Hemming and others (1989), Barker and Kopp (1991), Gregg and Karakus (1991), Machel (2000), Lavoie and others (2001), Coniglio and others (2003), and Lavoie and Morin (2004).

Previous Work

There is no known published work to date on the application of CL petrography on Pennsylvanian rocks from the Blanding sub-basin. Unpublished work includes observations of carbonate cements and dolomites in thin sections from Ismay zone outcrop samples along the San Juan River and from five Ismay zone cores in Ismay field by Brinton (1986).

Methodology

The analysis done in this study was completed using uncovered, polished thin sections, although rock chips and unpolished thin sections could be used. The equipment needed for CL can be installed on almost any polarizing microscope (see Marshall, 1988; Miller, 1988). A Nulcide Corporation luminocope model (figure 6; see also Marshall, 1988) belonging to the Colorado School of Mines Department of Geological Engineering was used for this analysis. Operating conditions were generally at 10-12kV accelerating potential, 0.5-0.7 mA of beam current and a beam focused at ~2 cm. All the work involved visual observations and some photographic documentation. Photomicrographs were taken using Fuji 1600 ASA color negative film. No attempt was made to measure intensities or spectral information on the CL responses (for example Marshall, 1991; Filippelli and Delaney, 1992) to the Ismay and Desert Creek samples. Image analysis and regional mapping of cement zones (that is “cement stratigraphy”) have been done by some workers on carbonate cements (for example Meyers, 1974, 1978; Dorobek and others, 1987; Cander and others, 1988; Dansereau and Bourque, 2001), but these applications are beyond the scope of diagenesis documentation attempted in this project.

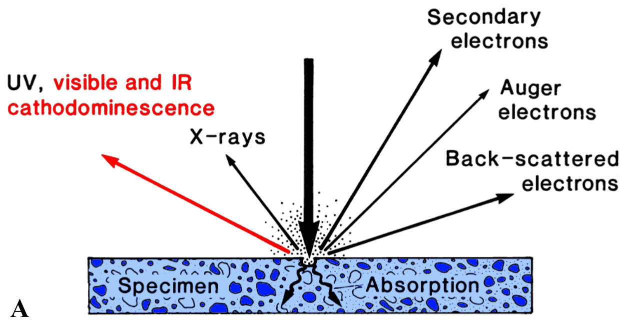
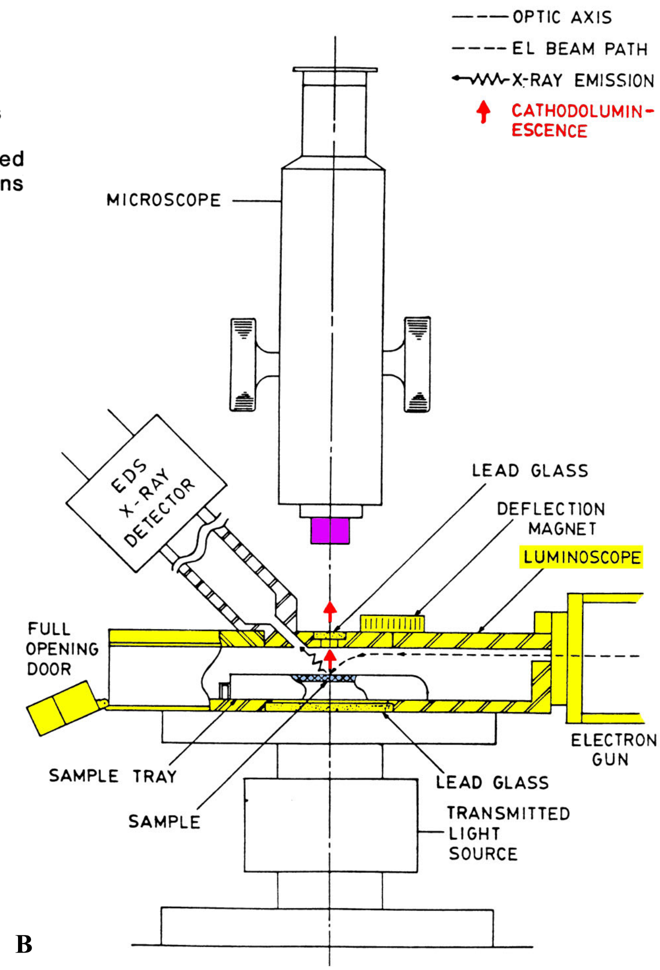
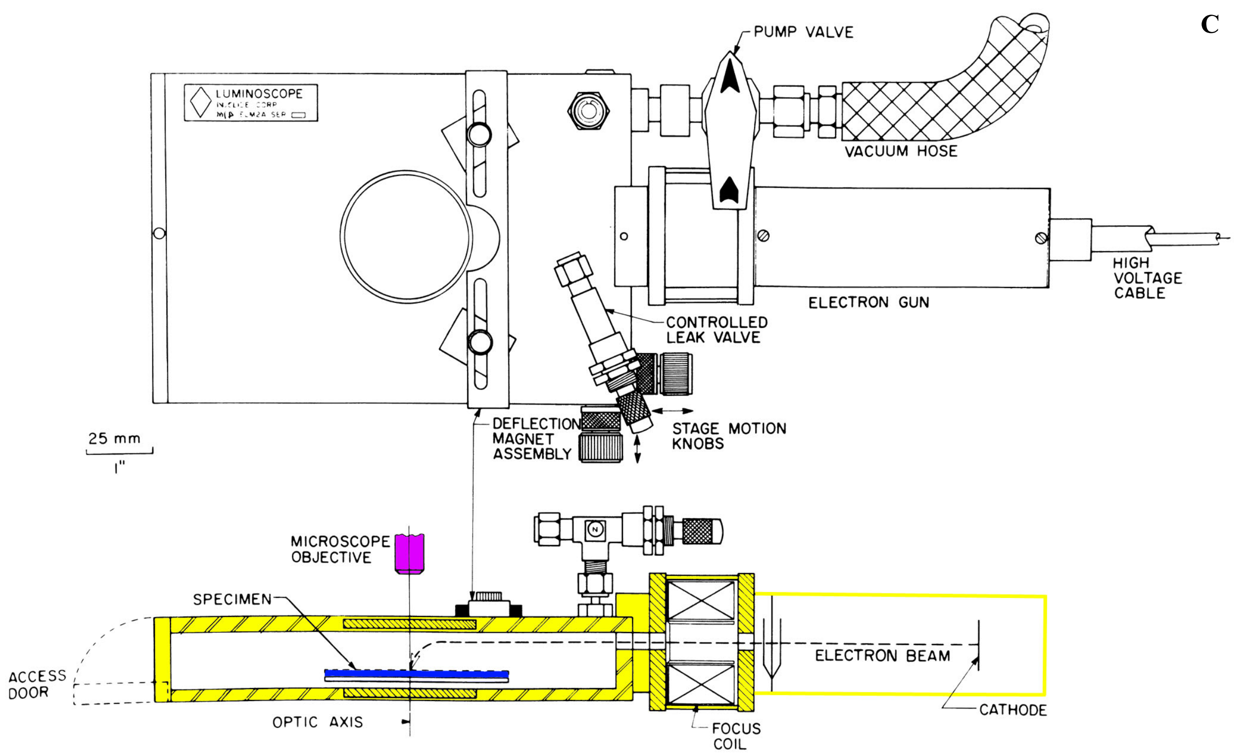


Figure 6. Generalized microscope optical configuration for observing cathodoluminescence (A modified from Walker and Burley, 1991; B modified from Marshall, 1991; and C modified from Marshall, 1988).





Cathodoluminescence Petrography of Upper Ismay and Lower Desert Creek Limestone and Dolomite Thin Sections

Cathodoluminescence examination was completed on five thin section samples from the upper Ismay zone limestones and dolomites within Cherokee field, and five samples of lower Desert Creek zone dolomite thin sections in Bug field (table 1; figures 2 and 4). These thin section samples were selected to be representative of mineralogical (for example calcite, dolomite, anhydrite, and quartz), compositional, diagenetic, and pore types encountered within one core from the upper Ismay limestones of Cherokee field and within four cores from the lower Desert Creek dolomites of Bug field.

In the Appendix of **Deliverable 1.2.6 – Thin Section Cathodoluminescence: Cherokee and Bug Fields, San Juan County, Utah**, there are 34 representative paired CL and transmitted plane light (Pl) photomicrographs from two of the Cherokee Federal No. 22-14 well upper Ismay samples, and five of the lower Desert Creek samples throughout Bug field. In addition, short descriptive captions are included adjacent to each photomicrograph.

Table 1. Upper Ismay (Cherokee field) and lower Desert Creek (Bug field) samples used for cathodoluminescence microscopy.

Well	Depth	Comments
Cherokee Fed. 22-14	5773.9	Tight dolomite with no visible fabrics or differences under CL. No photomicrograph examples in this report.
Cherokee Fed. 22-14	5778.1	Micro-porous dolomite; only dim to no visible CL differences. No photomicrograph examples in this report.
Cherokee Fed. 22-14	5821.2	Radiating cement crystals & microporosity. No photomicrograph examples in this report.
Cherokee Fed. 22-14	5836.8	Micro-zoned dolomite cements & bladed to equant calcite cements. Three pairs of photomicrographs included in report.
Cherokee Fed. 22-14	5870.3	Saddle dolomite replacement of limestone matrix & saddle dolomite cements. Three pairs of photomicrographs included in report.
May Bug 2	6306	Dolomitized micro-fibrous botryoidal cements. Two pairs of photomicrographs included in report.
May Bug 2	6312	Zone mega- and micro-dolomite crystals within brecciated fabric. Four pairs of photomicrographs included in report
Bug 10	6327.9	Alternating tight and streaks within dolomites. Three pairs of photomicrographs included in report.
Bug 13	5930.6	"Soil" pisolites and coated grain aggregates (grapestone?). Two pairs of photomicrographs included in report.
Bug 16	6300.5	Micro-box-work dolomite. One pair of photomicrographs included in this report.
TOTAL	**10 thin sections**	**18 CL-PL pairs of photomicrographs included in this report.**

Cathodoluminescence Petrography of Upper Ismay Thin Sections at Cherokee Field

Cathodoluminescence microscopy was completed on core sample thin sections with a variety of rock textures and diagenetic phases from the upper Ismay zone limestones within the Cherokee Federal No. 22-14 well (table 1). However, only two of the five samples showed any significant visible response to CL. The following remarks summarize our findings.

Cherokee Federal No. 22-14 well, 5836.8 feet: Cathodoluminescence imaging provides good to excellent resolution of grains (both skeletal and non-skeletal) as well as different generations of calcite cements within the limestone in this thin section (figures 7 and 8). Fine details of the microstructures within skeletal fragments, such as brachiopods, bryozoans, and phylloid-algal plates, are more readily visible under CL than with transmitted plane light. In addition, calcite cements that rim leached skeletal grains, as well as early generations of isopachous cements, can be easily seen. Some of the cements display a series of concentric bright and dull luminescent bands that represent multiple generations of cementation under varying water chemistries. Such concentrically banded cements are similar to those cements used in calcite cement stratigraphy within Carboniferous carbonate systems in North America by Meyers (1974, 1978, 1991) and Goldstein (1988, 1991). Finally, CL makes it easier to see the pore outlines and boundaries than under plane light viewing. Thus, it becomes possible to qualitatively interpret how interconnected the remaining pore systems are within this sample.

Cherokee Federal No. 22-14 well, 5870.3 feet: Cathodoluminescence imaging was very useful in identifying the presence of saddle dolomites (Radke and Mathis, 1980) within microporous dolomites in this sample from the Cherokee Federal No. 22-14 well core. Large dolomite crystals (1.0 to 2.0 mm in diameter) with distinctly curved crystal faces occur as both replacements of finer, earlier dolomites and as pore-filling cements (figures 9 and 10). These saddle dolomites display dull, red luminescence in their core areas and slightly bright, orange-red luminescence toward their rim areas. In addition, CL makes it possible to see the growth bands in these coarse dolomite crystals due to slight luminescent differences between each growth zone.

In general, the presence of saddle dolomites within a carbonate sample is indicative of the growth of strained, slightly iron-rich, dolomite replacements and cements under elevated temperatures during burial conditions (Radke and Mathis, 1980). Additional published descriptive work on saddle dolomites using CL may be found in Lavoie and Morin (2004).

Cathodoluminescence Petrography of Lower Desert Creek Thin Sections at Bug Field

Cathodoluminescence microscopy was completed on core sample thin sections exhibiting a variety of rock textures and diagenetic phases from the lower Desert Creek zone dolomites within the May Bug No. 2, Bug No. 10, Bug No. 13, and Bug No. 16 wells (table 1). The following remarks summarize our findings.

May Bug No. 2 well, 6306 feet: Cathodoluminescence imaging was used to examine the details of early, fibrous, marine cements that occur as distinct botryoidal fans within this Bug field sample of lower Desert Creek reservoir dolomites (figure 11). Most of these fibrous cements exhibit fairly uniform orange and red luminescence. Hints or ghosts of the radiating cement fibers are visible. The blunt to squares ends of several radiating bundles of fibrous cements can be seen. These blunt ends have been used by some carbonate workers (Frank and others, 1982; Goldstein, 1988, 1991) to suggest original aragonite mineralogy of these cements, since modern aragonite botryoidal cements exhibit similar morphologies. In addition, small, internal dissolution pores crossing these early marine cements are also more readily visible using CL.

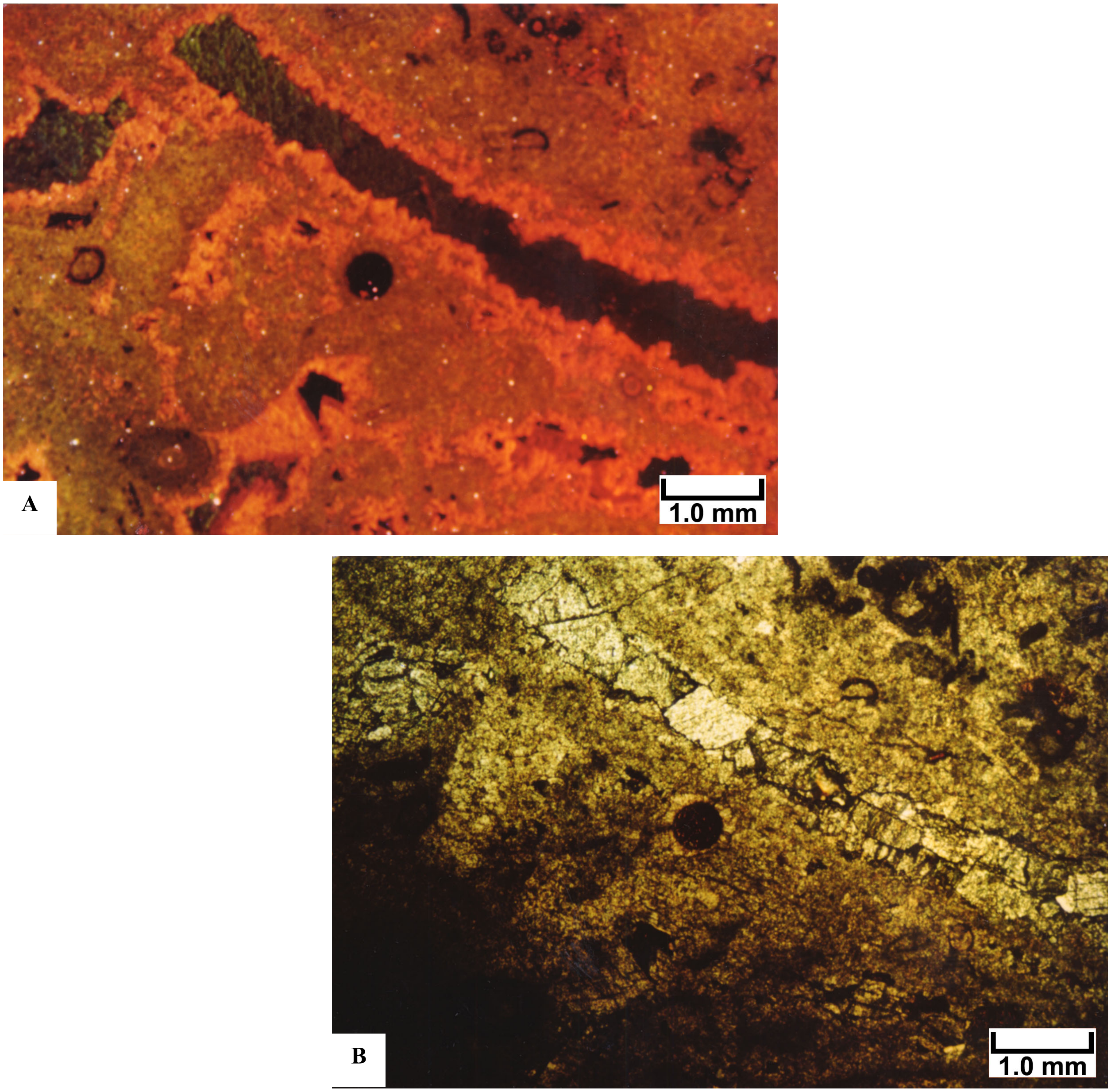


Figure 7. Photomicrographs from Cherokee Federal No. 22-14 well at 5836.8 feet. A - Cathodoluminescence overview of a representative skeletal/peloidal grainstone shows the details of grain preservation as well as different generations of calcite cement. Note the elongate non-luminescent area (from the upper left to right-central portions of this photomicrograph) which represents a dissolved phylloid-algal plate which is now a moldic pore. Other non-luminescent (black) portions of this view are also open pores or are filled with the same generation of calcite cement. A series of banded bright and dull cement generations represent an earlier generation of pore-filling cements. B - The same field of view is shown here under Pl at the same magnification. Note that the preservation of original grains, leached skeletal grains such as the dissolved phylloid-algal plate, and the multiple generations of cement are not visible under plane light. Without CL, many of these features would be difficult to identify.

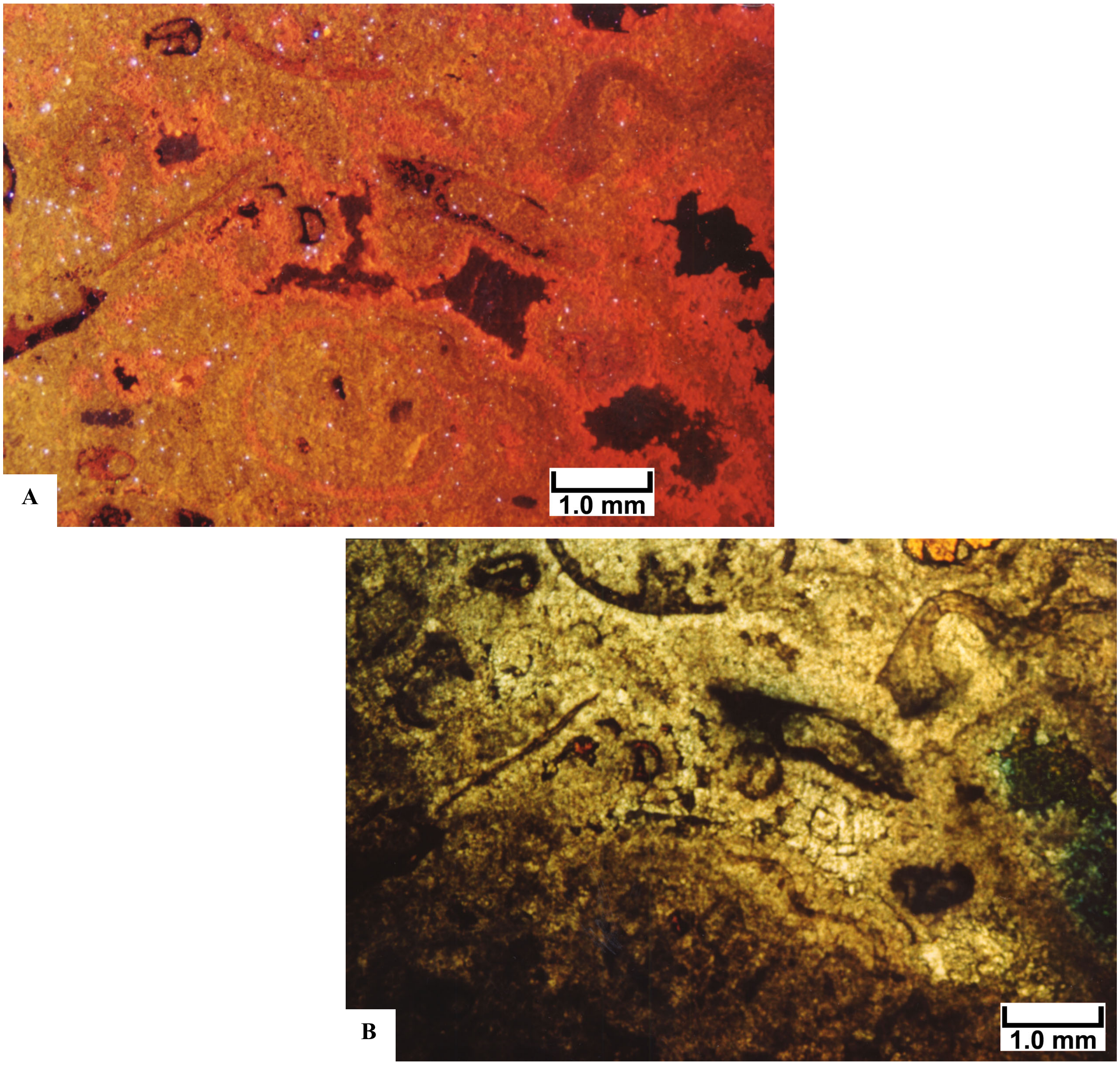


Figure 8. Photomicrographs from Cherokee Federal No. 22-14 well at 5836.8 feet. A - This CL view shows various skeletal grains in the dull red shapes and colors surrounded by banded generations of early pore-filling cements. Note the non-luminescent (black) patches that represent largely secondary pores that have either been filled with equant calcite spar cement, or are isolated, open moldic pores. The numerous light blue specs across this photomicrograph are mostly detrital quartz silt grains within this carbonate sediment. B - The same field of view is shown here under Pl at the same magnification. Vague outlines of skeletal grains, including broken phylloid-algal plates, brachiopod shells, and bryozoan fragments, are seen in the dark grains. This view does not provide much detail to differentiate various generations of calcite cement seen in CL view above.

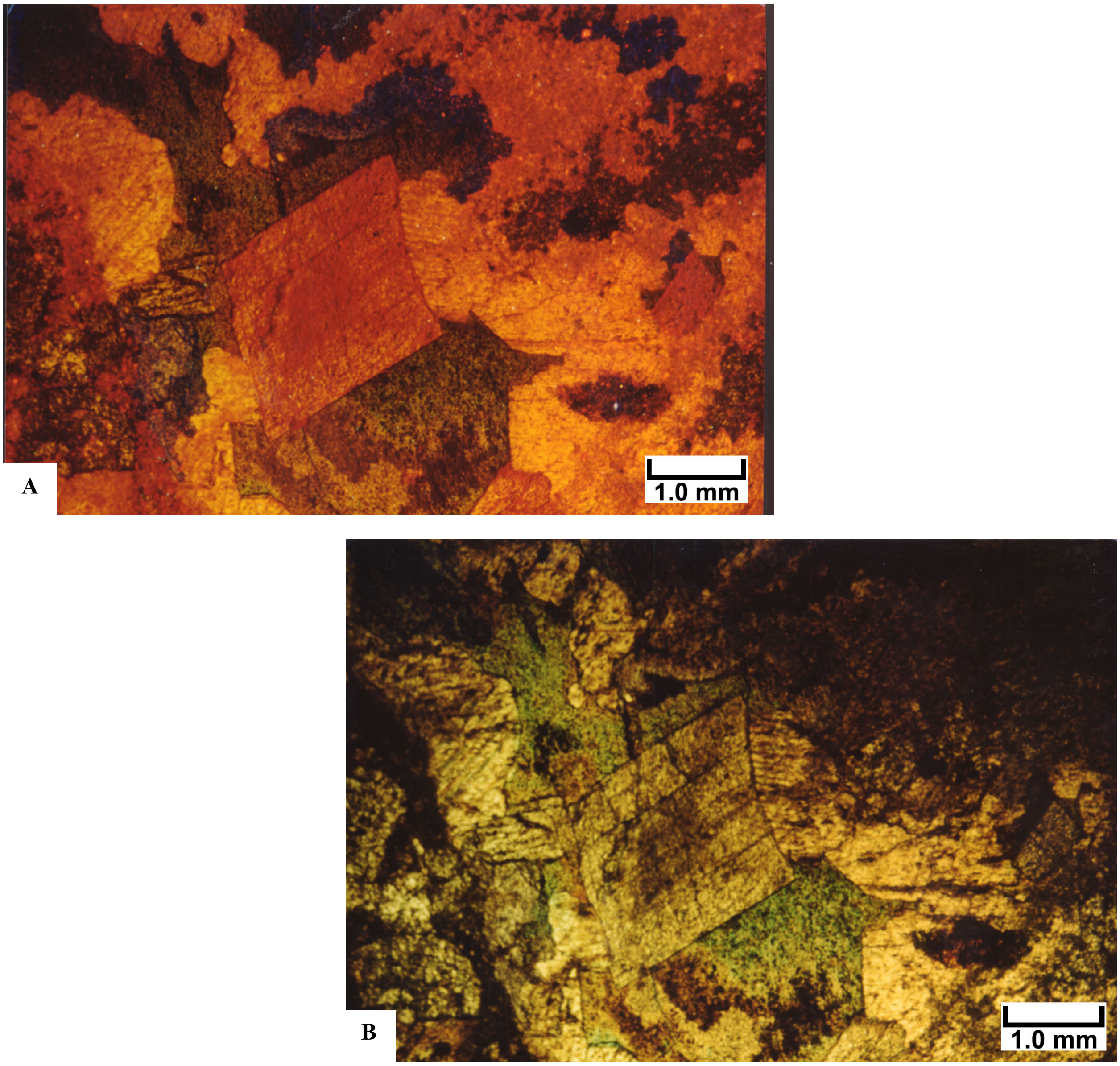
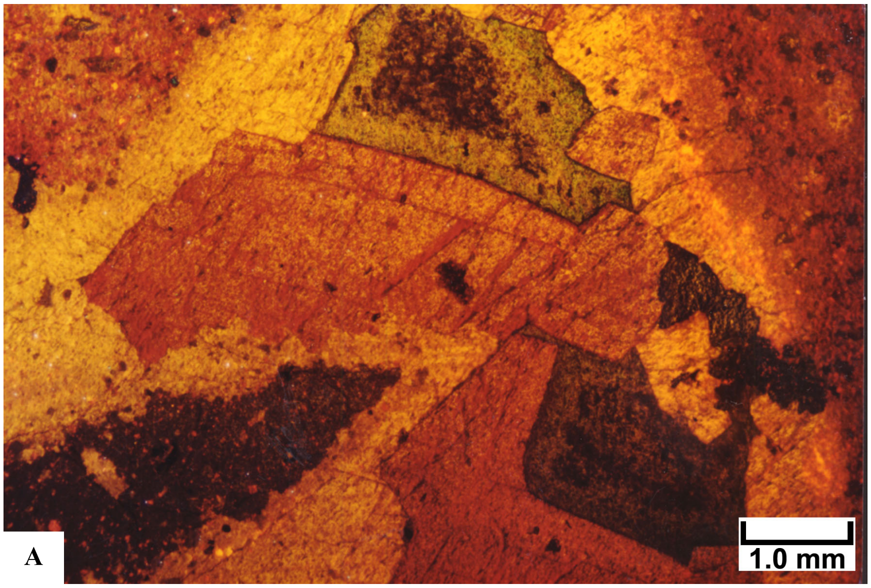


Figure 9. Photomicrographs from Cherokee Federal No. 22-14 well at 5870.3 feet. A - Most of the large crystals in this CL view consist of dolomite. Note in particular that the large crystal in the center displays strongly curved crystal faces. This "saddle dolomite" (see Radke and Mathis, 1980) as well as the other coarse dolomite crystals with reddish luminescence are probably late, burial or hydrothermal dolomites that precipitated under elevated temperatures. B - The same field of view is shown here under cross-polarized light at the same magnification. Note the sweeping extinction within the large crystal in the center, indicative of a strained crystal lattice. The bluish areas surrounding these replacement dolomites are remnants of intercrystalline pores.



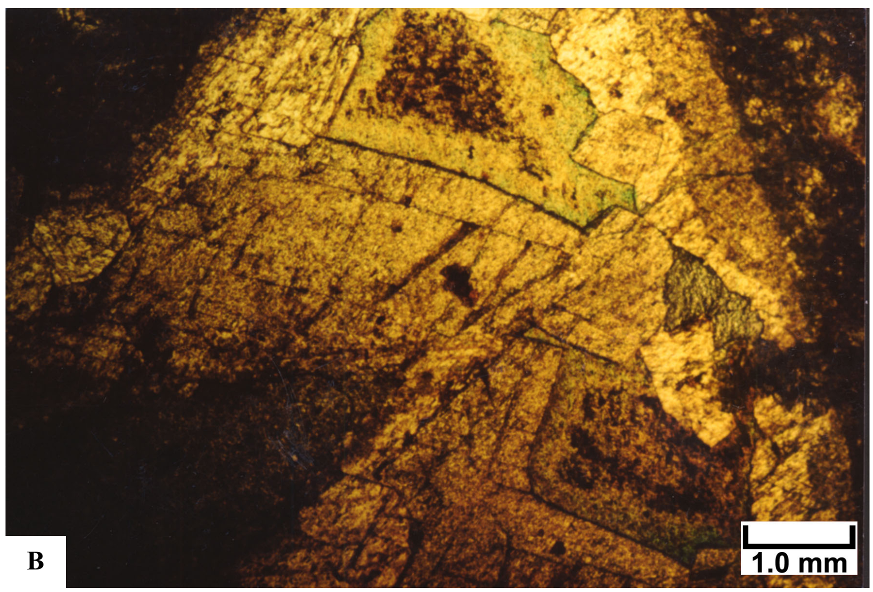


Figure 10. Photomicrographs from Cherokee Federal No. 22-14 well at 5870.3 feet. A - This CL view shows remnants of a muddy limestone matrix (wackestone) in the lower left and upper right corners of this photomicrograph that has been partially replaced by coarse dolomite crystals displaying curved faces. These "saddle dolomites" have a distinctive dull red and orange luminescence in which hints of the dolomite growth bands can be seen. Small inclusions of dark-colored, lime, wackestone matrix can be seen scattered throughout the coarse dolomite saddles, indicating that these saddle dolomites are replacing previous carbonates rather than being entirely cements. B - The same field of view is shown here under cross-polarized light at the same magnification. Note the intercrystalline pores (blue areas) between some of the saddle dolomites. This view makes it possible to see where dolomite has replaced lime wackestone matrix (in the medium and dark brown areas) and where dolomite is a cement growing into open pores (the clear areas).

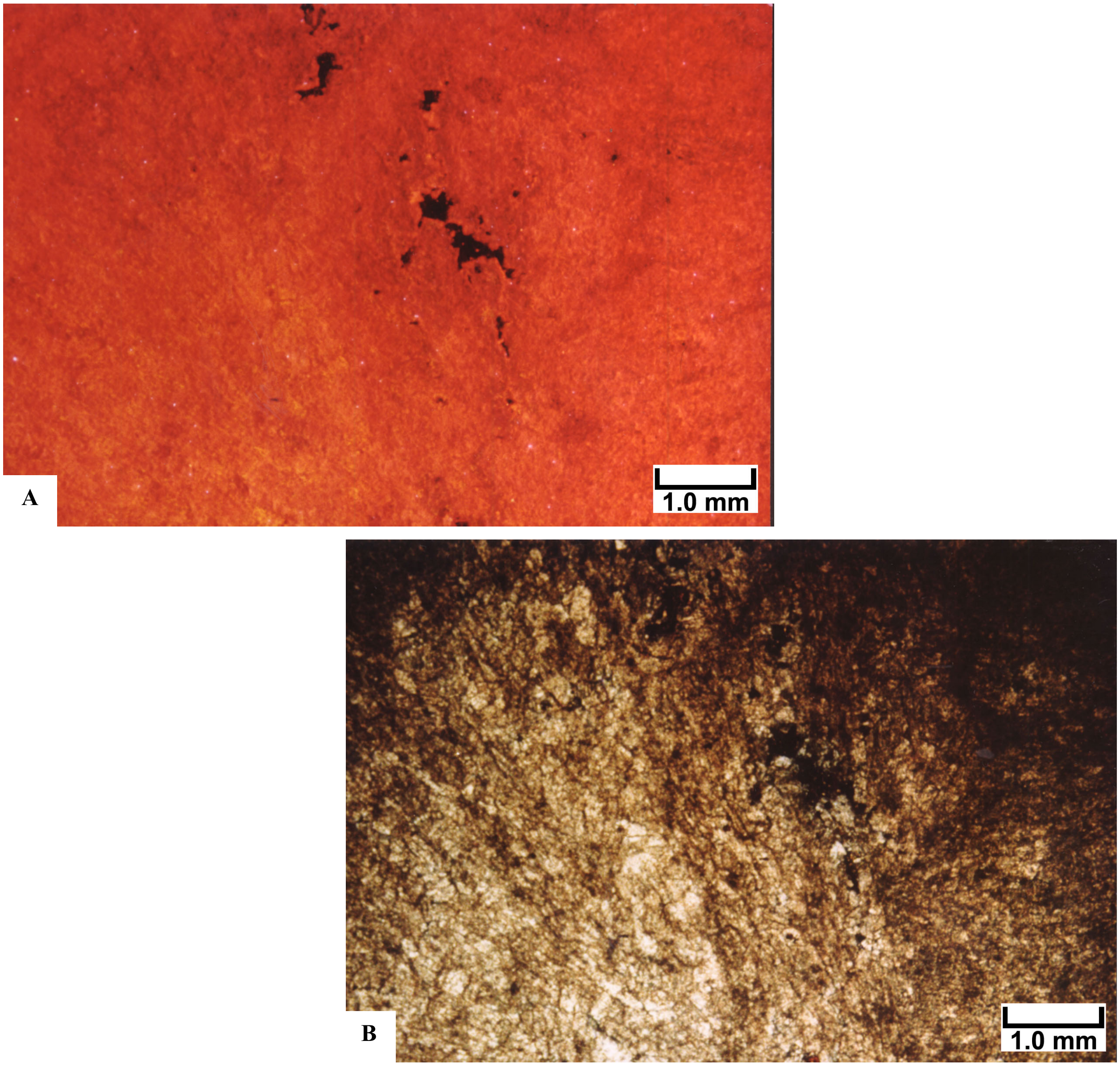


Figure 11. Photomicrographs from May Bug No. 2 well at 6306 feet. A - Cathodoluminescence imaging of a large botryoidal fan of dolomitized cements (originally aragonite) shows reasonably uniform orange and red luminescence. Note the blunt-shaped or square-ended crystal bundles evident in the area just to the right of center. Hints of radiating fibrous cements can be seen from bottom of the photograph to the top in this view. The black (non-luminescent) patches represent secondary pores within these early marine botryoidal cements. B - The same field of view is shown here under Pl at the same magnification. This photomicrograph shows ghosts of the radiating fibrous crystal habit of these completely dolomitized, early marine botryoidal cements. Without the CL view (see A above), it would be difficult to see either the blunt crystal fan terminations or the dissolution pores.

<u>May Bug No. 2 well, 6312 feet:</u> The dolomites replacing brecciated phylloid-algal mound fabrics are distinctly zoned when viewed under CL (figure 12). Replacement dolomite crystals and crystal aggregates that average 100 to 200 μm display dull to non-luminescent cores and bright red luminescent rims. In one of the photomicrographs from this sample, up to four growth zones can be seen within individual dolomite rhombs. The resulting dolomitization and crystal size growth creates small sucrosic crystals that form an effective intercrystalline pore system. These intercrystalline pores augment the vuggy and shelter pores created by the brecciated phylloid-algal mound fabric. Cathodoluminescence imaging makes it easier to see the contacts between dolomite matrix and pores. Cathodoluminescence brings out significant detail in areas of anhydrite replacement of the dolomitized sediment. Islands of red luminescing dolomite can be easily seen within the plethora of bladed-anhydrite crystal aggregates. Within other portions of this sample, carbonate grains such as peloids and fragmented skeletal debris can be distinguished from carbonate cements in this completely dolomitized interval. The dolomitized grains exhibit deep red colors under CL while the carbonate cements are bright reddish orange. Finally, CL does an excellent job in imaging microfractures and microfracture swarms cutting through the lower Desert Creek dolomites. In this sample, an orthogonal set of microfractures cuts across the thin section. Most of these microfractures can be seen as the dark-gray to black (non-luminescent) curvilinear lines. It is possible that some of these open microfractures may have originated from dissolution along microstylolites.

<u>Bug No. 10 well, 6327.5 feet:</u> Cathodoluminescence imaging of this sample was particularly useful in identifying the shape and distribution of phylloid-algal plates, even though most of the plates have been partially dissolved, lined with early cements, and dolomitized (figure 13). Micro-box-work arrays of bladed dolomite crystals are also very distinctive. In addition, CL provides a very vivid image of the distribution of both megapores and micropores within this dolomite. In particular, CL provides sharp definition of the pore boundaries with the dolomite matrix and crystal boundaries. Evidence of a brecciated fabric, as well as dissolution and corrosion of early sediments and cement, are easier to identify in this sample under CL than under plane polarized light.

<u>Bug No. 13 well, 5930.6 feet:</u> This sample consists of dolomitized pisolites and coated grain aggregates (similar to "grapestone"). Cathodoluminescence imaging aids in distinguishing the smaller grains incorporated into the grapestone, or aggregate grains, versus the early marine cements (figure 14). Portions of this sample consist of internal sediment composed of carbonate mud and silt-sized, detrital quartz. The pelleted nature of the muddy portion of this sample is very evident under Cl, despite the complete dolomitization of this interval. Interestingly, detrital quartz silt grains of probable eolian origin are easily visible within the internal sediments of this sample. In addition, cathodoluminescence imaging makes it much easier to see the open (versus cemented) pores and microfractures within this sample.

<u>Bug No. 16 well, 6300.5 feet:</u> Cathodoluminescence imaging of this sample was particularly useful in identifying dense, dolomitized, micro-box-work arrays as well as bundles of fibrous marine cements (figure 15). Original grains and cement fabrics can be seen in the brighter red portions of the luminescing dolomites. Somewhat later cements and zonation within coarser dolomites can be seen in the orangish-red areas. Cathodoluminescence imaging also provides sharp definition of rhombic dolomite crystal terminations as well as intercrystalline pores.

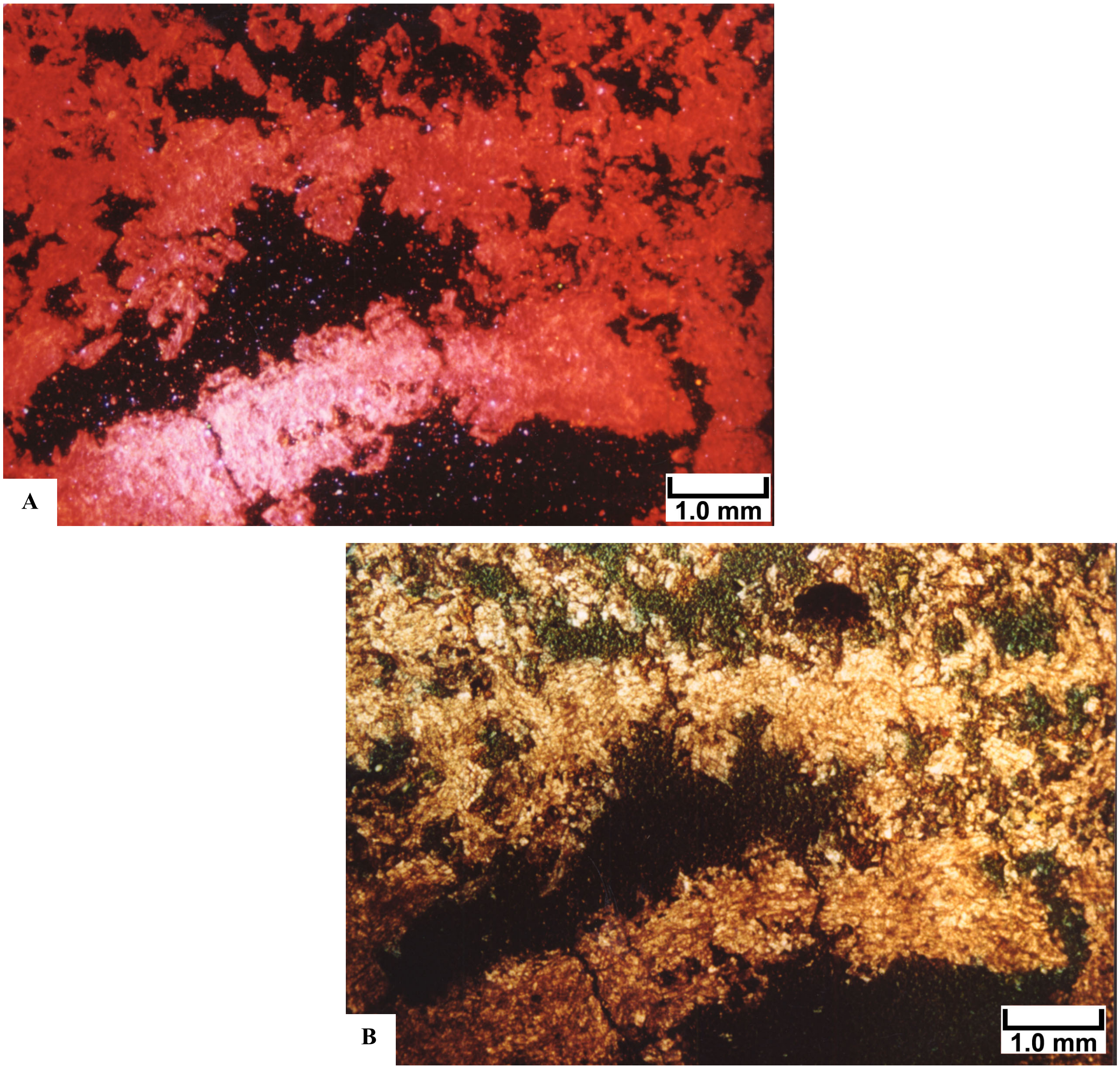


Figure 12. Photomicrographs from May Bug No. 2 well at 6312 feet. A - This CL view nicely shows micro-rhombic dolomites that have completely replaced a brecciated phylloid-algal mound fabric. Despite the dull red luminescence of these dolomites, growth zones and different crystal sizes can readily be seen within the replacement fabric. For instance, note the dolomite crystals (in the upper center portion of this photomicrograph) with dead (black) cores and bright luminescent (red) rims. This zonation is probably related to two distinct growth stages of this replacement dolomite. The resulting dolomitization of this mound fabric creates small sucrosic or rhombic crystals that produce an effective intercrystalline pore system. The large black patches in the lower half of this photomicrograph consist of open pores within this brecciated phylloid-algal mound fabric. B - The same field of view is shown here under Pl at the same magnification. Note that there is very little detail within this replacement dolomite that is visible under plane-transmitted light. For instance, it is impossible to see any of the zoned dolomite rhombs or the precursor fabrics before dolomite replacement without the use of CL.

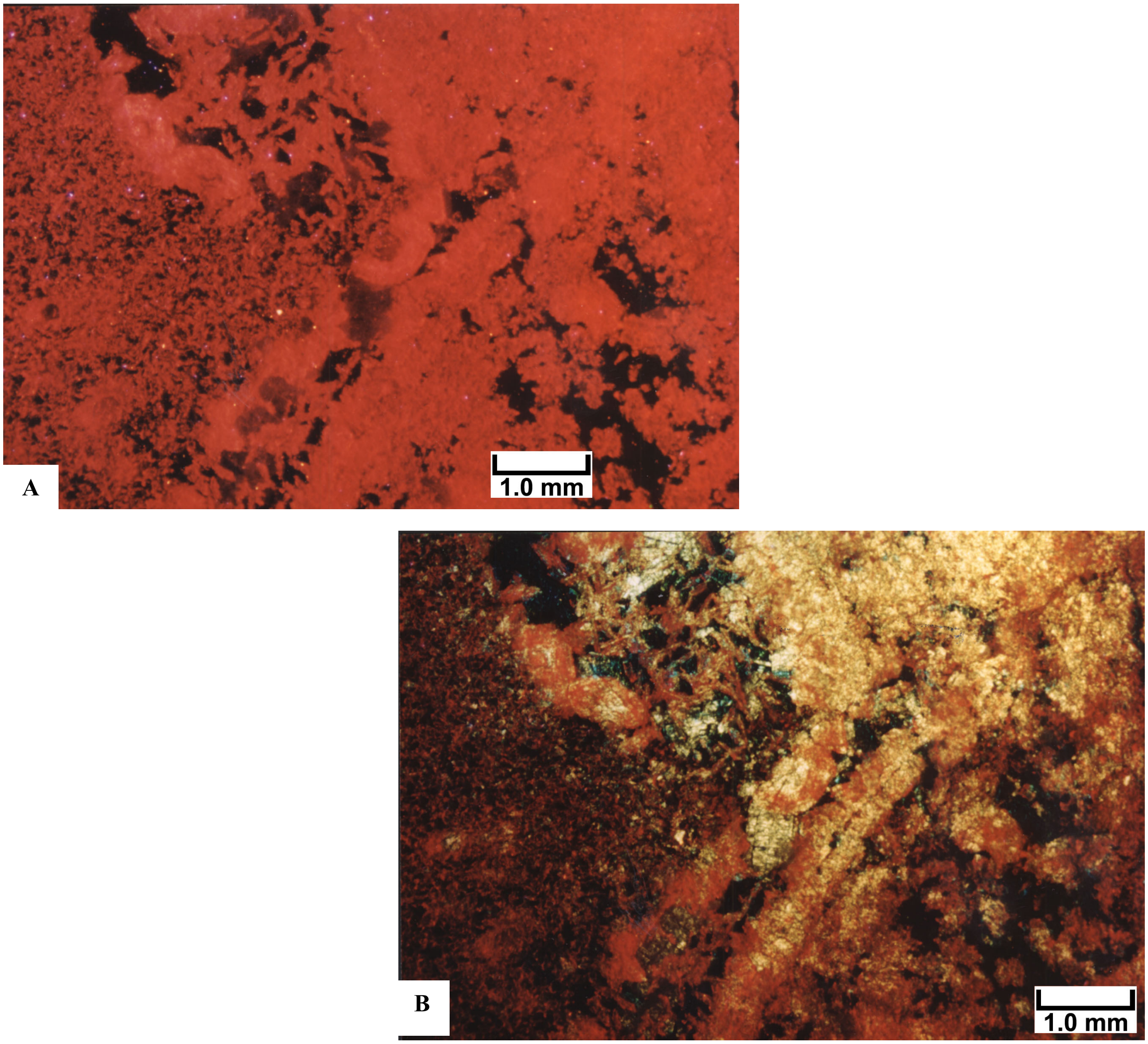
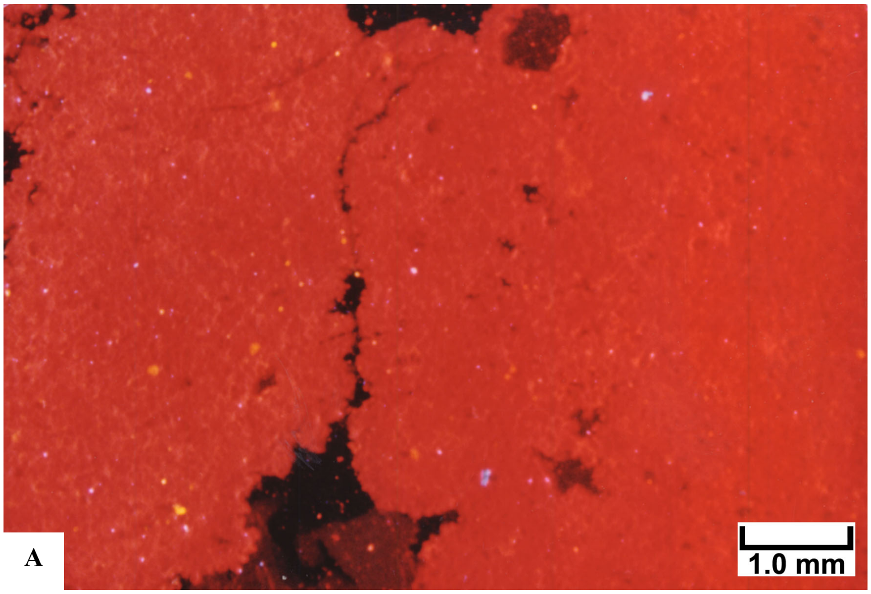


Figure 13. Photomicrographs from Bug No. 10 well at 6327.5 feet. A - Cathodoluminescence imaging clearly shows some of the distinctive fabric elements within a completely dolomitized, phylloid-algal/skeletal, grain-rich sediment. Note the elongate blades of poorly preserved phylloid-algal plates from bottom center to upper right in this photomicrograph. Within these blades are preserved remnants of skeletal materials in bright red, and cements in dull reddish gray. For the most part, dolomitized skeletal grains, or their remnants, appear as bright red luminescent areas with clear skeletal shapes. Some of the grains easily visible in this field of view are rounded crinoids with their distinctive circular cores and single crystal, red luminescent rims. Early cements (prior to dolomitization) are very dull red. Porous microdolomites dominate the left quarter of this photomicrograph. Note also the remnants of dolomitized bladed cements and micro-box-work dolomite fabrics visible in the upper left center of this view. The black areas throughout this field of view are open pores. B - The same field of view is shown here under combined Pl and CL (that is, a double exposed image) at the same magnification. In this view, remnants of bright red luminescence show through the coarse and fine dolomite crystal patterns. The blue and black areas of this slide consist of open pores.



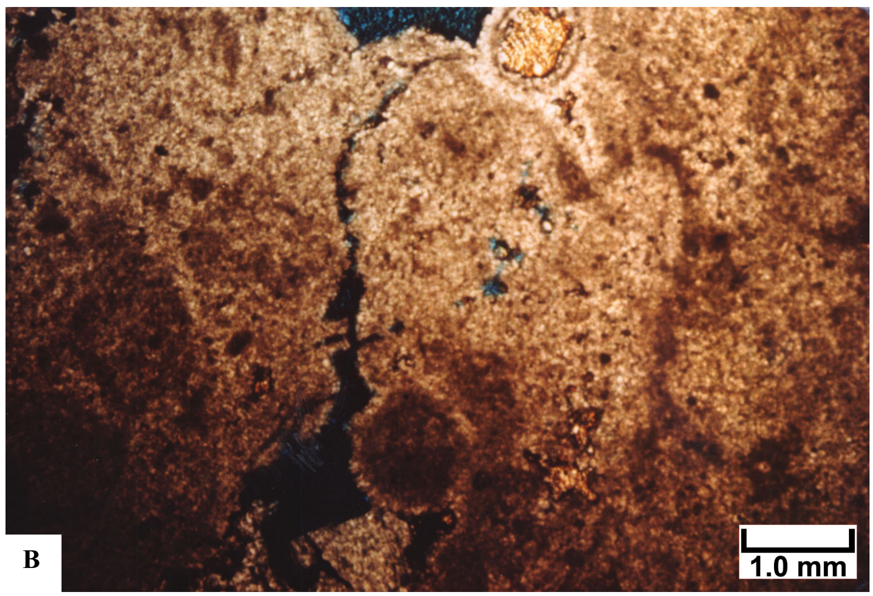
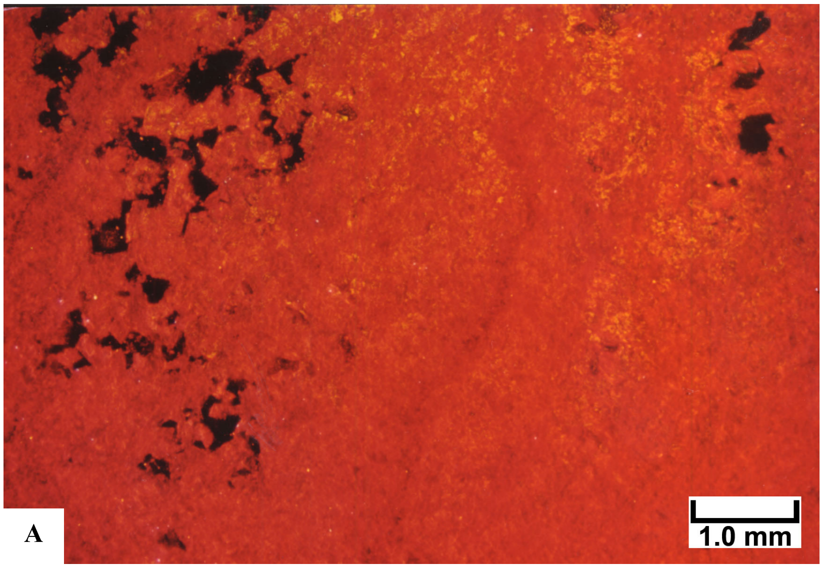


Figure 14. Photomicrographs from Bug No. 13 well at 5930.6 feet. A - This CL view is from a sample of pisolites and coated-grain aggregates. Note that it is possible to see the carbonate-grain outlines (in uniformly dull red) versus early carbonate cements (in orangish red). Late-stage, dolomitized, spar crystals can be seen in the dull-gray patches in the lowermost and uppermost center of this view. The black (non-luminescent) areas clearly image the open pores and microfractures. B - The same field of view is shown here under Pl at the same magnification. In this view, it is possible to see the large coated grain aggregates (pisolites and possible grapestones). However, Pl viewing does not show the individual carbonate grains that compose the larger grain aggregates as well as the CL imaging.



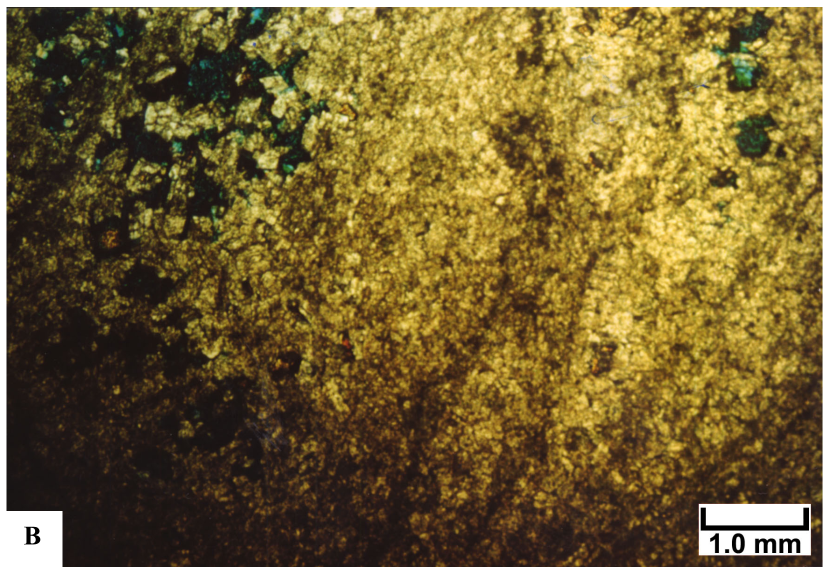


Figure 15. Photomicrographs from Bug No. 16 well at 6300.5 feet. A - Cathodoluminescence of an area displaying micro-box-work dolomite and early fibrous marine cements is imaged here. Note the patterns of dull red, bright red, and orangish red throughout this dense, tight dolomite. Most of the original carbonate fabric associated with carbonate sediment and early marine cements can be seen in the dull and bright red patterns. The orangish red areas represent later dolomite cement growth bands. In some areas of this view (especially in the left third of the image), there are dolomite crystals that have developed a clear rhombic shape. The black areas clearly define open pores associated with dissolution as well as the development of intercrystalline porosity. B - The same field of view is shown here under Pl at the same magnification. Only the outlines of larger dolomite crystals are visible here. Cathodoluminescence imaging, as shown above, brings out the internal original fabric versus later dolomite growth zones much more clearly. The blue patches are open pores lined with black bitumen. The presence of bitumen makes it difficult to clearly discern the outlines of dolomite matrix versus open pores under Pl. Cathodoluminescence (above) images the pore/rock boundaries very well.

TECHNOLOGY TRANSFER

The UGS is the Principal Investigator and prime contractor for three petroleum-research projects, including two in the Paradox Basin. These projects are designed to improve recovery, development, and exploration of the nation's oil and gas resources through use of better, more efficient technologies. The projects involve detailed geologic and engineering characterization of several complex heterogeneous reservoirs. The Class II Oil Revisit project, described in this report, includes a practical oil-field demonstration of selected technologies in the Paradox Basin. The second Paradox Basin project will evaluate exploration methods and map regional facies trends for independents interested in the Mississippian Leadville Limestone play. The third project is part of the DOE Preferred Upstream Management Practices (PUMP II) program. That project, titled *Major Oil Plays in Utah and Vicinity*, will describe and delineate oil plays in the Utah/Wyoming thrust belt, Uinta Basin, and Paradox Basin. The DOE and multidisciplinary teams from petroleum companies, petroleum service companies, universities, private consultants, and state agencies are assisting with the three projects.

The UGS intends to release selected products of the Class II Oil Revisit Paradox Basin project in a series of formal publications. These publications may include data, as well as the results and interpretations. Syntheses and highlights will be submitted to refereed journals, as appropriate, such as the *American Association of Petroleum Geologists (AAPG) Bulletin* and *Journal of Petroleum Technology*, and to trade publications such as the *Oil and Gas Journal*. This information will also be released through the UGS periodical *Survey Notes* and be posted on the UGS Paradox Basin project Web page.

The Technical Advisory Board advises the technical team on the direction of study, reviews technical progress, recommends changes and additions to the study, and provides data. The Technical Advisory Board is composed of 13 field operators from the Paradox Basin (Seeley Oil Co., Legacy Energy Corp., Pioneer Oil & Gas, Hallwood Petroleum Inc., Dolar Oil Properties, Cochrane Resources Inc., Wexpro Co., Samedan Oil Corp., Questar Exploration, Tom Brown Inc., PetroCorp Inc., Stone Energy LLC., and Sinclair Oil Corp.). This board ensures direct communication of the study methods and results to the Paradox Basin operators. The Stake Holders Board is composed of groups that have a financial interest in the study area including representatives from Utah and Colorado state governments (Utah School and Institutional Trust Lands Administration; Utah Division of Oil, Gas and Mining; and Colorado Oil and Gas Conservation Commission), Federal Government (U.S. Bureau of Land Management and U.S. Bureau of Indian Affairs), and the Ute Mountain Ute Indian Tribe. The members of the Technical Advisory and Stake Holders Boards receive all semi-annual technical reports and copies of all publications, and other material resulting from the study.

Utah Geological Survey *Survey Notes* and Web Site

The purpose of *Survey Notes* is to provide non-technical information on contemporary geologic topics, issues, events, and ongoing UGS projects to Utah's geologic community, educators, state and local officials and other decision makers, and the public. *Survey Notes* is published three times yearly. Single copies are distributed free of charge and reproduction (with recognition of source) is encouraged. The UGS maintains a database that includes those companies or individuals (more than 300 as of October 2004) specifically interested in the Paradox Basin project or other DOE-sponsored UGS projects. They receive *Survey Notes* and notification of project publications and workshops.

The UGS maintains a Web site, http://geology.utah.gov. The UGS site includes a page under the heading *Oil, Gas, Coal, & CO_2*, which describes the UGS/DOE cooperative studies past and present (Paradox Basin, Ferron Sandstone, Bluebell field, Green River Formation, PUMP II), and has a link to the DOE Web site. Each UGS/DOE cooperative study also has its own separate page on the UGS Web site. The Paradox Basin project page http://geology.utah.gov/emp/Paradox2/index.htm contains (1) a project location map, (2) a description of the project, (3) a list of project participants and their postal addresses and phone numbers, (4) a reference list of all publications that are a direct result of the project, (5) semi-annual technical progress reports, and (6) project technical poster displays.

Project Publication

Chidsey, T.C., Jr., and Eby, D.E., 2004, Heterogeneous shallow-shelf carbonate buildups in the Paradox Basin, Utah and Colorado: targets for increased oil production and reserves using horizontal drilling techniques – semi-annual technical progress report for the period April 6, 2003 to October 5, 2004: U.S. Department of Energy, DOE/BC15128-9, 22 p.

Phase II Field Demonstration Proposals

The UGS issued a press release (see Appendix) seeking proposals from operators to drill a lateral(s) from an existing vertical well(s) or new horizontal well(s) in the Ismay and Desert Creek zones of Paradox Basin fields in Utah or Colorado, as part of the Phase II Field Demonstration. The operator will receive 35 percent (up to $200,000) of the drilling cost. This offer was the result of decisions by the operators of the Cherokee and Bug fields not to conduct horizontal drilling activities at this time. Parties interested in conducting horizontal drilling in fields they operate must provide the following information: (1) a geologic overview of the field, (2) targeted zone(s), (3) depth, length, and directions of proposed horizontal wellbore(s), (4) drilling rationale, (5) drilling cost summary (AFE), and (6) drilling timetable.

CONCLUSIONS AND RECOMMENDATIONS

1. Examination of upper Ismay limestones and lower Desert Creek dolomites under CL makes it possible to more clearly identify grain types and shapes, early cements (such as botryoidal, fibrous marine, bladed calcite cements), and brecciated phylloid-algal mound fabrics. In addition, identification of pelleted fabrics in muds, as well as various types of skeletal grains, is improved by CL examination in rocks where these grains have been poorly preserved, partially leached or completely dolomitized. In many ways, CL imaging of samples nicely complements the types of information derived from epifluorescence of carbonate thin sections.

2. Cathodoluminescence imaging clearly and rapidly images pore spaces that cannot be easily seen in standard viewing under transmitted, plane-polarized lighting. In addition, the cross sectional size, shape, and boundaries of pores are easy to determine. This information is often very useful when considering the origin and timing of dolomitization as well as evaluating the quality of the pore system within the dolomite.

3. Imaging of microfractures as well as dissolution along microstylolites, is greatly facilitated under CL. Many open microfractures cannot be easily seen in a normal 3-µm–thick petrographic thin section, especially within dense, lower Desert Creek dolomites. Routine CL examination of the same thin section often reveals the presence of individual microfractures or microfracture swarms.

4. Examination of saddle dolomites, when present within the clean carbonate intervals of the upper Ismay or lower Desert Creek interval, can provide more information about these late, elevated temperate (often hydrothermal) mineral phases. For instance, saddle dolomites from the Cherokee Federal No. 22-14 well showed nice growth banding. They also exhibited the difference between replacement and cement types of saddle dolomites under CL.

ACKNOWLEDGMENTS

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Core and petrophysical data were provided by Burlington Resources, Seeley Oil Company, and Wexpro Company. The Nuclide ELM 2-R Luminoscope used for this study is part of the instrumentation in the Department of Geological Engineering, Colorado School of Mines. John Humphrey assisted with the setup and instruction on this instrument.

James Parker and Cheryl Gustin of the Utah Geological Survey (UGS) drafted the figures. The report was reviewed by David Tabet and Michael Hylland of the UGS. Cheryl Gustin, UGS, formatted the manuscript for publication.

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APPENDIX

UTAH GEOLOGICAL SURVEY PRESS RELEASE

State of Utah

Department of Natural Resources

Utah Geological Survey

ROBERT L. MORGAN
Executive Director

RICHARD G. ALLIS, PH.D.
State Geologist/ Division Director

OLENE S. WALKER
Governor

GAYLE F. McKEACHNIE
Lieutenant Governor

NEWS RELEASE

January 12, 2005
Contact: Tom Chidsey
(801) 537-3364

UTAH GEOLOGICAL SURVEY OFFERS DOE FUNDING FOR HORIZONTAL DRILLING IN THE PARADOX BASIN

The Utah Geological Survey (UGS), with funding from the U.S. Department of Energy (DOE), is offering operators of fields that produce from the Ismay and Desert Creek zones of the Pennsylvanian Paradox Formation in the Blanding sub-basin, Paradox Basin, Utah and Colorado, the opportunity to receive 35 percent, up to a maximum of $200,000, of the costs to drill a horizontal lateral(s) from an existing vertical development well(s) or a new horizontal development well(s). All results from this government-funded horizontal well, including production tests, drilling and completion reports, daily production, geophysical well and mud logs, core and cuttings, etc., will be in the public domain. The general public, as well as UGS and DOE officials, will be permitted to visit the well site during drilling, testing, and production phases of operation.

Interested parties are invited to submit proposals to the UGS by March 1, 2005, that include the following information: (1) a geologic overview of the field, (2) targeted zone(s), (3) depth, length, and direction(s) of proposed horizontal wellbore(s), (4) drilling rationale, (5) drilling cost summary (AFE), and (6) drilling timetable.

For further information concerning horizontal drilling proposals, please contact Roger Bon (Ph.: 801/537-3363; email: rogerbon@utah.gov) or Tom Chidsey (Ph.: 801/537-3364; email: tomchidsey@utah.gov).

The drilling of a horizontal well is part of a UGS/DOE-funded project titled *Heterogeneous Shallow-Shelf Carbonate Buildups in the Blanding Sub-Basin of the Paradox Basin, Utah and Colorado: Targets for Increased Oil Production and Reserves Using Horizontal Drilling Techniques*. The UGS maintains a Web site, http://geology.utah.gov which includes a page under the heading *Oil, Gas, Coal, & CO_2*, describing the UGS/DOE cooperative studies past and present. Each UGS/DOE cooperative study also has its own separate page on the UGS Web site. The Paradox Basin project page http://geology.utah.gov/emp/Paradox2/index.htm contains (1) a project location map, (2) a description of the project, (3) semi-annual technical progress reports, and (4) project technical poster displays.

The Utah Geological Survey is an applied scientific agency that creates, interprets, and provides information about Utah's geologic environment, resources, and hazards to promote safe, beneficial, and wise use of land.

1594 West North Temple, Suite 3110, PO Box 146100, Salt Lake City, UT 84114-6100
telephone (801) 537-3300 • facsimile (801) 537-3400 • *geology.utah.gov*